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Piloting participatory smartphone mapping of intertidal fishing grounds and resources in northern Mozambique: Opportunities and future directions

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Prof. Dr. Victor N. de Jonge
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Dear Prof. Dr. de Jonge,

20 September 2016

We thank you for the opportunity to submit our revised manuscript “Piloting participatory smartphone mapping of intertidal fishing grounds and resources in northern Mozambique: opportunities and future directions” to Ocean and Coastal Management.

We are grateful for the comments of the two reviewers and addressed the issues raised in their comments by changes to the manuscript or explanations, where we could not fully incorporate their suggestions. Please find all responses to the reviewers’ comments as well as a revised manuscript version in the online submission system.

Thank you for considering the revised manuscript to Ocean and Coastal Management. If you have any questions, please do not hesitate to contact me and I will do my utmost to provide further information you require.

Yours sincerely

A handwritten signature in black ink that reads "Sophie Paul". The script is cursive and fluid, with the first letters of the first and last names being capitalized and prominent.

Sophie Paul

Piloting participatory smartphone mapping of intertidal fishing grounds and resources in northern Mozambique: opportunities and future directions

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Highlights

CyberTracker proves to be a useful tool for participatory mapping.

The research focuses on fisherwomen, a key but vulnerable resource user group.

We offer suggestions for women's inclusion into fisheries management.

The intertidal maps are a valuable tool for community-led resource management.

Abstract

The participation of local communities in marine resource management can contribute to the sustainability and longevity of marine resources across diverse coastal settings. In contexts where there are low levels of formal education and high levels of illiteracy, and where marine resource management is governed predominantly by customary management systems, the introduction of formal marine resource management can be challenging. Maps are often required as the basis for spatial marine management measures, effective spatially-explicit fisheries monitoring, and for formal support from fisheries authorities. Our research with local women reef gleaners of Cabo Delgado, in northern Mozambique, pilots the potential uses of smartphones and digital mapping as a tool to allow fishers to map these understudied intertidal fishing grounds, and to understand the ecological dynamics as well as social uses of the intertidal resources. Even though women are key food and income providers through intertidal resource gleaning in this area of Mozambique, they have limited roles in fisheries management decision making. Therefore, we developed a participatory approach to mapping that could act as an entry point for their involvement in the design of a spatial fisheries management plan and associated community monitoring. Fisherwomen were trained to use smartphones with CyberTracker software for mapping intertidal fishing grounds in their village, and the locations of intertidal resources most important to their livelihoods, including octopus, pen shells and oysters. Interviews and focus groups were conducted throughout the mapping process to ascertain women's use and interest in the technology. We conclude that community-based mapping through simple tools as developed in this research can help connect local community groups, bridge traditional and formal governance systems and provide a positive example of co-management in practice.

Keywords

Participatory mapping; intertidal fishing grounds; CyberTracker; fisheries co-management; Mozambique;

1 Introduction

The overexploitation of coastal marine resources remains a major threat to the food security and overall quality of life for many subsistence coastal communities who are dependent upon these resources (Wong et al., 2014). The accelerating pace and scale of extraction is rapidly reducing the overall ecological integrity and biodiversity of these resources, which normally would provide a variety of ecosystem services from fisheries to coastal protection (Jackson et al., 2001). Worldwide, as finfish stocks are overexploited and catch declines, fishermen and fisherwomen increasingly rely on accessible intertidal marine invertebrates for food and income (Anderson et al., 2011).

Sustainable management of intertidal stocks has been compromised from limited incorporation of local knowledge on ecological processes, together with social and economic benefits often not flowing to the communities who own or live adjacent to the resource source areas (Basurto et al., 2013). This situation is particularly poignant in remote coastal communities throughout much of the developing world, where intertidal resources are governed and managed predominantly by customary *de facto* management systems, and for which there is little integration with more formal, science-based, government-led *de jure* management (Mackinson and Nøttestad, 1998; Béné and Neiland, 2006). It is now broadly recognized that the participation of local fishers and their representing institutions is a prerequisite to connecting formal science-based marine management measures, with community knowledge and engagement, as seen with the expansion of Locally Managed Marine Areas (LMMAs) in the West Indian Ocean (WIO) (Roccliffe et al., 2014). Developing suitable tools and approaches that allow for the integration of local ecological knowledge and scientific knowledge is critical for communities and scientists working together to develop effective marine management measures. We directly examine this nexus through the lens of participatory mapping of the intertidal fishing areas in Mozambique.

1.1 Sustainability and livelihood importance of intertidal harvesting

For decades, invertebrates were considered to be more resilient to fishing and harvesting pressure than other fish stocks due to the large geographic ranges they occupied and their relatively short life cycles (Jamieson, 1993; Carlton, 1993). Evidence from recent studies suggests, however, that invertebrate populations are quite heavily affected (Basurto et al., 2013), on top of other pressures such as climate change and pollution (Harley et al., 2006). A recent study in Tanzania showed significant and quantifiable decreases in invertebrate abundance from overharvesting, with gastropod and bivalve abundances decreasing by over 60% during the five year study period seemingly due to harvesting pressures (Fröcklin et al., 2014). As most invertebrate species are sessile, relatively immobile or territorial, overharvesting can easily become a major challenge in either areas with large human populations, such as the Philippines, and in areas with lower densities, but where the local communities are highly dependent upon local harvesting (Richmond, 2011).

Despite the combination of declining finfish resources and increasing economic value of invertebrate fisheries, formal management of intertidal areas is rare, and where present remains largely unregulated and unmonitored (Anderson et al., 2011). The lack of formal management regimes for invertebrate species may be connected to historically low valuation of these resources, as it was often presumed that artisanal subsistence fisheries have limited ecological impact and did not contribute significantly to national economies (Barnes-Mauthe et al., 2013).

Many coastal communities across the WIO rely on marine resources for subsistence and income, with seafood providing the principal source of protein (Jiddawi and Öhman, 2002). Marine invertebrates, such as octopus and oysters, are essential intertidal resource and are primarily hand-gleaned by women, children, and elderly, particularly during low spring tides (Richmond, 2011). Men also dive for invertebrates such as oysters and octopus in deeper sub-tidal areas adjacent to the intertidal. For women, gleaning enables direct acquisition of both protein or cash income in communities where agricultural production is only sufficient for subsistence purposes (Rosendo et al., 2011). In Mozambique, where 60% of rural households incomes are spent on food, additional sources of cash income are essential, particularly to female-headed households without additional income sources (Republic of Mozambique, 2008). Additionally, these resources can provide a safety net in times of food scarcity, as reef gleaning is generally less risky and more predictable than fisheries further offshore or than agriculture (Tucker et al., 2013).

In coastal areas where invertebrate resource extraction is increasing, local communities, and particularly women, are reliant upon effective sustainable management of these resources. Co-management legislation introduced in Mozambique in 1990 (Blythe et al., 2013) provides a management mechanism, allowing community fishing councils (Conselhos Comunitários de Pesca – CCPs) to take on responsibility for management of marine resources in collaboration with the government (ADNAP, 2012). The CCPs are responsible for areas between two points along the shoreline, and three nautical miles out to sea (Garnier et al., 2008).

1.2 The role of participatory fishing ground mapping in intertidal resource management

A precursor to formal marine monitoring and management measures is the need for basic information on species status, combined with accessible and repeatable forms of mapping and assessments of invertebrate status to initiate, and continue, essential monitoring protocols and management regimes. A map of a community fishing ground, and the principle intertidal resources found within this area, is essential to establish locally meaningful spatial units for management. It is also important for long term monitoring of ecological change to ensure that data collection is spatially explicit to accurately understand trends in catch and Catch Per Unit Effort (CPUE) data (Ling and Milner-Gulland, 2006). In addition to these practical requirements for maps, legislation can often require a map as the basis of a formal management plan. In Mozambique, while there is no specific requirement in fisheries legislation for CCPs to have maps, the recent conservation legislation requires a management plan and a zoning plan, with a classification of the area and geographical limits (Lei de conservação, 2014). Communities wishing to formally register an LMMA as a community conservation area, will need maps with a specific zoning plan.

Fishermen and fisherwomen in coastal communities rarely document this type of spatial knowledge in written format, but have excellent spatial knowledge of the fishing grounds, the names, and resource type and status within these areas (Daw et al., 2011). Participatory Rural Appraisal (PRA) techniques, such as participatory resource mapping, were developed in the 1980s specifically to capture and integrate this knowledge into environmental and development plans, and prevent outside groups misinterpreting local realities (Chambers, 1994a; Chambers, 1994b; Chambers, 1997). Despite the existence of PRA techniques for mapping, in Mozambique maps are rarely accessible to fishers but mostly available and common for government, NGOs and the private sector.

For these reasons, community-led mapping and monitoring, as well as citizen science, has become popular as a tool to bridge gaps between local knowledge and more formal systems of resource management (Spellerberg, 2005). Such processes can also provide other contributions, e.g. the mapping can build the capacity and interest of local people, educate, promote awareness of environmental change, and empower communities to be at the center of the process rather than rely on outside experts (Chambers, 1997; Spellerberg, 2005; Lawrence, 2006; Conrad and Hilchey, 2011). Local people often have a deeper understanding, trust and reliance on their own data more than expert data (Danielsen et al., 2005). This said, participatory map creation and community-based monitoring is not without its critics, where there can be concerns over scientific rigor and accuracy of approaches (Spellerberg, 2005). Consequently, while there might be a “trade-off between community involvement and scientific rigor” (Aswani and Weiant, 2004, p.309), the long-term merits of the local participatory learning can result in more sustained monitoring, buy-in to management measures based on locally-produced data, and scope to incorporate and validate local ecological knowledge.

1.3 Use of smartphone technology for participatory fishing ground mapping

Our research aimed to put these ideas into practice using an innovative technology in the form of the smartphone application CyberTracker, to explore the potential opportunities for the application of this technology in the development of local fishing ground maps for local fisheries management plans, and potentially even fisheries monitoring, in the context of the WIO. This research project is unique in utilizing the smartphone for Global Positioning System (GPS) data collection, and based on the understanding that electronic recording methods are often more suitable for data collection compared to paper-based methods because they are faster and less susceptible to transcription errors (Rogers et al., 2010).

While there is clearly excitement about the potential applications of simple technologies such as GPS units and CyberTracker technology, researchers still sound cautionary notes on the use of technology in natural resource management projects. In some cases, Western technology has raised expectations of development benefits in communities. There is also the danger of masking underlying development

problems when relying on a technical fix (Kaplan, 2006). We highlight that the technology should be used as a tool within a comprehensive participatory strategy and CyberTracker hence is a tool and not a solution.

This paper presents research from a coastal fishing village in northern Mozambique. The overall objective of the research was to understand if participatory mapping of intertidal fishing grounds with smartphones could generate resource location and use maps, and if these maps had potential for practical use in marine management planning by communities in the context of fisheries co-management in Mozambique, and whether this mapping process could increase the involvement of women in the co-production of knowledge and fisheries co-management more generally. Specifically, we asked the following questions: i) are fisherwomen able and adept at using the smartphone and the CyberTracker application, and what could be improved about the tool?; ii) is it feasible for women fishers to map both intertidal fishing grounds and intertidal resources effectively using smartphones and the application?; iii) do the resulting maps have the potential to act as a useful tool for marine monitoring and co-management planning ?; iv) is the use of this approach and tool a good entry point to integrating fisherwomen's knowledge into marine monitoring and management?

2 Materials and methods

2.1 Study area

The study was conducted in Quiwia village, Cabo Delgado Province, northern Mozambique and the surrounding intertidal zone used by women from the village and fishers from surrounding satellite villages (Figure 1). The research involved two fieldwork periods in Quiwia village. The objective of the first fieldwork period (October – November 2013) was to understand the principle intertidal resources for women's livelihoods in Quiwia village. With this knowledge, the CyberTracker application was designed remotely. During the second fieldwork period (May - June 2014) the research team worked with fisherwomen to refine the application, and to map the intertidal fishing grounds and the key intertidal resources within these areas. This data was downloaded in the field, and maps were made remotely to be then verified again by fishers in Quiwia.

The research was conducted in collaboration with the Our Sea Our Life (OSOL) project, a fisheries co-management and livelihood development project that aims to support the Mozambican government to meet its Convention on Biological Diversity targets through the implementation of LMMAs. The study area of this work is considered as being the area within which the mapping tool could be applied and replicated if found useful by coastal communities (Figure 1).

Figure 1: Map showing the location of Quiwia village (yellow dot), and the larger study area with five villages (red dots) in which CyberTracker could also be used if found useful.

Quiwia village has a population of approximately 860 inhabitants, for whom fishing and agriculture are key livelihood activities (Rosendo et al. *in prep*). Women are predominantly occupied with agriculture (rice, cassava, maize), intertidal harvesting, and mat making. Men also practice agriculture, but focus on fishing and trade. The octopus fishery is a key source of cash income for both men and women. The intertidal area of Quiwia village includes mangroves, reef flats, seagrass beds and sandy stretches. The mangrove area is used for the collection of local construction material and mangrove crabs, the reef flats contain edible shells, harvested by women and children, and octopus, predominately harvested by women in the rocky parts of the intertidal flats, and men in the sub-tidal zone. There are also neighboring satellite villages around Quiwia, predominantly occupied by itinerant fishers, including Farol and Makongo. Although there was no local fishing committee (CCP) in Quiwia village at the time of the research, a committee has been established in 2015.

2.2 Research team

The lead author led the research, and fieldwork was conducted in collaboration with the Mozambican non-governmental organization Associação do Meio Ambiente (AMA) which is the lead implementing partner on the OSOL project. Three AMA project officials acted as research assistants throughout the field periods, facilitating focus group discussions, working with community leaders and fishers, and participating and assisting in the mapping work in the field.

2.3 Designing the CyberTracker application

CyberTracker is a free GPS data collection software and was selected for this research as it has a simple icon-based user interface. It was originally designed by the non-profit CyberTracker Conservation organization for working with illiterate natural resource users, piloted with hunter-gatherers, in order to allow them to map important natural resources and communicate this to a broader audience (CyberTracker Conservation, 2013b, 2013c). With illiteracy rates among women over 20 to 80% (INE, 2013), CyberTracker was considered appropriate for working with fisherwomen in coastal Mozambique. The software allows for observations to be easily recorded and saved with coordinates of their location to subsequently be visualized on maps.

The process for the design and development of the application, including specific steps is shown in Figure 2.

Figure 2: Flow chart of the design and development process of the application, showing the time the activity was carried out and how long the activity took, an explanation of the activity and an overview of the participants to highlight participatory actions.

To populate the user interface, it was first important to understand the key intertidal resources used by women in coastal communities within the study area. This information was collected using PRA techniques such as seasonal calendars, transect walks and focus groups as part of the OSOL project's livelihood baseline in November 2013, the first fieldwork period. The focus group discussions aimed to determine and rank the intertidal resources based on their economic and food security importance to women. The results illustrate that oysters, octopus, pen shells and small fish caught with mosquito and other nets of small mesh sizes (*Madada*¹) are the most important resources for women (Table 1).

Table 1: Key reported intertidal resources used by women in the OSOL project villages.

Lalane	Nsange Ponta	Quifuki	Quirindi	Quiwia
Oysters	Oysters	Octopus	<i>Madada</i>	Octopus
<i>Madada</i>	Pen shells	<i>Madada</i>	Octopus	Oysters
Pen shells	Octopus	Sea cucumbers	Pen shells	Pen shells
Table note: octopus: <i>Octopus cyanea</i> , oysters: <i>Pinctada spp.</i> , pen shells: <i>Pinna muricata</i>				

While the principle objective of using CyberTracker was to map the boundaries of the intertidal fishing grounds, (Application 1, Intertidal fishing grounds) it was also important to populate the user interface with icons representing the intertidal resources in Table 1 so that women could map the areas within each fishing ground where these intertidal resources are located (Application 2, Intertidal resources). Icons were developed from a CyberTracker set of icons (CyberTracker Conservation, 2013a), as well as from drawings of specific species from Richmond (2011), an example is shown in Figure 3. A list of resulting screens used is shown Table 2. One *Samsung Galaxy S Duos* and two *Huawei Ascend Y 300* phones paid by the Our Sea Our Life project were used for data collection.

Figure 3: Illustration of a CyberTracker screen showing intertidal resources icons used in the participatory mapping.

Table 2: A list of screens and their purpose.

Screen	Purpose
Observer	Choose number for each participant to record who entered the data
GPS Timer Track	Choose interval for automatic waypoints to be taken
Tide	Choose tide (neap tide, normal tide, spring tide, high spring tide)

¹ Words in italics are in the local language Kimacue

Weather	Choose weather (sunny, cloudy, rainy)
Zone*	Choose zone
Habitat	Choose habitat (sand, mud, rock, mangroves, seagrass)
Type of Animal*	Choose resource-type
Photo	Possibility to take a picture of e.g. an important geographic feature or resource
Field Note	Possibility to enter additional information in text format
*Table notes: Zone refers to intertidal fishing ground, but was used in the application as zone was easier to use in English and Portuguese with AMA facilitators. The screens Zone and Type of Animal were only used in Application 2 (intertidal resources mapping).	

2.4 Participant selection

PRA techniques as mentioned in section 2.3 were conducted with key fisherwomen in the first fieldwork period. Fisherwomen were selected and asked to participate by AMA extension workers who had been living and working in the villages for several months.

For the second stage of fieldwork, the mapping, the research team first introduced the research concept and goals to the village leaders. This introduction and explanation session was particularly important in this context to secure the initial support and ensure village leaders understood the research activities and objectives, prior to then working with women fishers. Criteria for involving fisherwomen in the research were discussed and agreed upon within the field team, and again with the village leaders. Criteria included a) women over 18; b) women who knew the intertidal area well, and c) women who regularly practice intertidal gleaning. Fisherwomen were recruited by the village vice-leader. In the beginning, only two women, who had been recruited before the start of the second fieldwork period, participated. The village vice-leader chose women whose education and experience in intertidal resource harvesting he considered suitable for this project. The location of intertidal fishing grounds and the main resource use areas is common knowledge in the village. A few participants are therefore sufficient to represent the knowledge and conduct the mapping. After the initial participant selection, the women were made responsible for finding more participants who met the criteria above. The number of women was limited to six, as three smartphones were available, leaving two women to work with each phone. This participant selection process took approximately one week, as each woman had to first gain permission from her husband to participate in the mapping. This fully consultative approach of selecting participants was extremely important, particularly in a small village such as Quiwia, where sensitivity to gender relations and local norms is critical to conducting research activities.

2.5 Application design for intertidal resources mapping

As the objective of the study was to map the different intertidal fishing grounds, the key intertidal resources found within these areas, and to understand if women could use the smartphones effectively for mapping, the first week after participant selection was spent working with women to introduce and understand the tool, the interface, and testing the phones in the intertidal areas. In the first few days it was clear the participants could not identify certain icons provided by CyberTracker, so photographs of key species were taken in the intertidal zone and added to the application. Although a variety of species were photographed, the mapping focused only on the key livelihood species (Table 1) - octopus, pen shells and oysters. Once the pre-testing was complete, participatory fishing ground mapping was conducted, and then intertidal resource mapping with the smartphones started daily during spring tide.

2.6 Mapping

Prior to fishing ground mapping with CyberTracker, participatory resource mapping was conducted during the first fieldwork period with a group of fishermen and -women from Quiwia who were intertidal harvesters. The exercise aimed to list the fishing grounds, and to determine positions for these areas, and intertidal resource use areas within these fishing grounds, in order to orientate the smartphone mapping. The map was made on the ground using stones, coconuts, and lines in the sand and then transcribed onto a large cloth by AMA staff.

Using the participatory map in the second fieldwork period, a routine was then developed to meet in the mornings for a short meeting to discuss the plan for the day. This helped everyone to understand what should be done on that day and to decide in which part of the intertidal mapping would take place on that day. Then the group went to the intertidal and mapped for two to four hours. The women took turns in mapping so all got the chance to learn how to handle the smartphone and CyberTracker. Nevertheless, all women mapped the same area, so that a comparison between the groups of women was possible. The researcher also mapped the fishing grounds and resources in order to ensure validation of data collected by the women and accuracy of the maps. Detailed field notes were taken to record how women adapted to the process and tool, and to specify when data was entered incorrectly. The limited number of participants ensured accuracy because close supervision was possible. For the maps to be more robust and meaningful to resource management, more fisherwomen should be included in the mapping. It is important to keep in mind, however, that a larger group of fishers was included in the participatory mapping exercise and therefore contributed knowledge about intertidal fishing ground locations and resources.

The smartphone mapping then occurred in two steps. The first step was to map the borders of intertidal fishing grounds, which all have specific names in Kimacue, and are normally associated with shoreline

features. The areas were mapped using Application 1, and included those areas that could be reached by walking as far as up to the hip in water, as these are the areas used by women. It was impossible to map the seaward boundaries of zones because they are too far out to be reached on foot. Once the fishing grounds had been mapped, the second step was for women to map the intertidal resource zones. Three intertidal resources including octopus (*Mweja*), oyster (*Imbare*) and pen shells (*Makaza*) were mapped by using Application 2. In this application women could choose the intertidal fishing ground, in which they would then map a specific resource.

Other minor changes were incorporated to the applications as problems arose. For example, women found it complicated to turn the phone back on from sleep mode, and so phone settings were adjusted so that the screen stayed on for 15 minutes before switching to sleep mode.

During data analysis, any incorrectly entered data points and test day points were excluded. Exact elimination was possible due to field notes specifying when data was entered incorrectly. Maps were generated from the cleaned data using CyberTracker software.

2.7 Informal and semi-structured interviews

Informal interviews and direct observations were conducted when mapping the intertidal zone in order to understand how participants were finding the mapping tool. In the village, three semi-structured group interviews were conducted during the neap tide and after the mapping process with the participating women to explore their views on resource collection and the usability of CyberTracker. The structure included discussion on the challenges of using CyberTracker, women's interest and perceived benefits of the use of CyberTracker, and an open discussion on other feedback on the process. The semi-structured interviews were carried out in groups of two to four women, as individual interviews with women, particularly when conducted with a male translator, were considered culturally inappropriate. Furthermore, the interviews were not voice-recorded in order to create a comfortable setting for the respondents and to ensure that they felt at ease. Detailed notes were taken during and after all interviews, and each group interview lasted approximately one hour. The interviews with the women were conducted in Kimacue, with the AMA project coordinator functioning as an interpreter. Possible biases and constraints from interpreting and the interpreter himself need to be kept in mind. The qualitative data was analyzed by descriptive coding through manual pen-and-paper methods as specified in Baralt (2011). Manual coding was seen as suitable considering the amount of data.

3 Results

3.1 Challenges and benefits to the use of CyberTracker

The use of smartphones was a new experience for the participants. Two women had never used a mobile phone before, and mobile phones used by the other women were not smartphones. The anticipated problems, such as visibility difficulties in bright sunlight and recognition of the small pictures on the hand held devices, were not identified as difficulties. The semi-structured interviews and direct observations did however identify a number of challenges that women fishers faced with the new technology.

The first two challenges to using the technology were linked to the smartphone hardware and menu screen, and women's inexperience with using smartphones. Firstly, women participants explained that their main challenge was switching the phones on and off as well as turning the phones back on from sleep mode. This is partly due to the need to press and hold the on and off buttons, which is not inherently evident to first time users. This issue was usually resolved after a few days of fieldwork, and no special adjustments were needed.

Secondly, navigating the smartphone overall phone menu in order to get to or get back to the CyberTracker application was a problem for most women. Sufficient practice before going out to the intertidal zone without a facilitator is advised. Removing other phone applications reduced the clutter and need to flick through screens to find the CyberTracker icon.

In addition to these two main issues with handling the phone, it was evident that the skill of using the smartphone and mapping application was quite quickly forgotten. This occurred between two tides for instance, and is due to the fact that smartphone use was new to all the women participants in this research.

Unsurprisingly, once inside the application, the third technical challenge was in choosing the correct option where only text options were available. This was only the case for mapping the intertidal resources, as it was impossible to have a generic icon for each intertidal fishing ground that can be chosen in Application 2, the name of each zone was entered as text. Even though the women participants insisted that reading was not a problem, during the first day of data collection it was clear that this method required the research assistants' help.

The last technical difficulties encountered were associated with screen modifications and the addition of screens during the course of the research. These changes confused the women when they were confronted with a previously unknown screen, for example when moving from Application 1 to Application 2.

377
378 Interestingly, despite these challenges to the use of the technology, particularly the smartphone itself,
379 at times women's lack of prior experience with smartphones also seemed to help their use of
380 CyberTracker. Women used the application as instructed during the training, whereas people with
381 prior touchscreen experience, for example AMA staff, had assumptions about how it would work: for
382 example, they tried to scroll through the application by moving their fingers across the screen, which
383 is not possible in CyberTracker.

384
385 Despite minor difficulties with regard to the hardware, and some to the application, participants'
386 interest in learning to properly operate the new technology could be seen in their questions to know
387 more about using the mapping application. Women also asked how to turn the phones on and off and
388 navigate through the menu screens in the first days. The application accommodates a photo screen,
389 which allows taking pictures if there is an important feature related to the location's GPS point. This
390 screen was mostly utilized to take pictures of rocks, trees, and other significant features when mapping
391 the borders of zones. New participants were extremely interested to learn how to take pictures for a
392 point, and women were also keen to explain the technology to the new participants.

393
394 In addition to the feedback on the use of the technology and the observations above, general feedback
395 about the mapping activity was obtained through interviews with women. The women described that
396 their time commitment towards the mapping work in the intertidal area was feasible and did generally
397 not impede their household tasks, as they are used to being out of the household harvesting or tending
398 fields for a major part of the day. Nevertheless, the mapping activity did mean they could not harvest
399 in the intertidal flat for the period of the research, meaning they lost out on an income source. This
400 was a significant opportunity cost for women's participation.

401
402
403 **Figure 4:** Women using the smartphones and CyberTracker application in the intertidal zone

404 405 3.2 Mapping of intertidal fishing grounds

406 The participants identified a total of 11 intertidal harvesting zones used by women of Quiwia village
407 (Figure 5 and Table 3). Intertidal fishing grounds are areas used for resource collection, with
408 boundaries and names easily recognized by women harvesters and usually defined by noteworthy
409 physical features, such as rock formations or large trees, and social features, such as houses, peoples'
410 fields or coconut plantations. The total coastline covered by these zones from west to east totaled
411 approximately 14 km.

412
413
414 **Figure 5:** All intertidal harvesting zones used by women from Quiwia village

Table 3: Quiwia's fishing grounds and their approximate areas in hectare (ha) as inferred from CyberTracker maps.

Fishing ground	Approximate area of the zone in ha	Main resources mapped in the fishing ground
Makongo kubwa	197	Oysters, pen shells
Makongo ndogo	52	Oysters, pen shells
Etumba	49	Oysters, pen shells
Quiwia	42	Pen shells
Kumayanga	35	Pen shells, octopus
Mbuyuni	12	n/a
Soelani	6	n/a
Ikongo	7	n/a
Acheni	139	Octopus
Farol	167	Octopus
Total area used for gleaning	706	

3.3 Mapping of intertidal resource zones

Within each of these 11 intertidal harvesting zones there are more specific areas in which women mapped the three key intertidal resources for their livelihoods (Table 1). Octopus are harvested across all of the rocky intertidal area, although women mapped only those areas where they reported high catches of octopus. It was clear that although women referred to an intertidal fishing ground name when discussing octopus harvesting they were referring to a core area within that zone where they harvest frequently. For example, using *Acheni* fishing ground, Figure 6 shows a core area used for octopus harvesting located off the sea grass and sandy shoreline, towards the subtidal area.

Figure 6: Acheni intertidal fishing ground and the core area used for octopus harvesting

Similarly, for oyster beds and areas with high abundance of pen shells, women walked around these areas with the smartphone, mapping the core areas for these resources. An example of a resulting map for one fishing ground (*Kumayanga*) is shown in Figure 7, which is used for both pen shells and octopus harvesting.

Figure 7: Kumayanga intertidal zone used for pen shells and octopus.

4 Discussion

This research set out to examine the potential use of innovative technology, in this case smartphone technology using the mapping application CyberTracker, to generate maps with potential for practical use in fisheries co-management planning, the establishment of LMMAs, and as a mechanism to

increase the involvement of women in the co-production of knowledge and fisheries co-management more generally (in Mozambique). The premise of this research is that for spatial intertidal management measures to be effective, they need to be based on meaningful spatial units - local fishing grounds - and with information on the location and abundance of intertidal resources. Additionally for management of such areas to be effective requires a combination of fishers' local ecological knowledge, and scientific knowledge (Mackinson and Nøttestad, 1998).

4.1 Usability and feasibility of smartphone mapping

This pilot research project shows that illiterate fisherwomen in northern Mozambique are able to use smartphones and the CyberTracker application to map intertidal fishing grounds and intertidal resources important to their livelihoods with minimal training and support as well as using simple technology.

While there were issues with the use of the phones themselves, the icon-based parts of the application were used with ease. This is tribute to the CyberTracker system itself, which was designed for use by non or semi-literate hunter-gatherer societies and has been applied broadly to map indigenous peoples lands and resources, for protected area management, and citizen science projects more broadly (CyberTracker Conservation, 2013b; Eades, 2015).

The use of the icon-based system makes the CyberTracker application inherently accessible in this context, but women also showed a real interest in the use of the smartphone itself and learning how to use it more generally. Although wanting to learn how to take pictures is not indicative of an interest in monitoring or mapping, women's continuous eagerness to learn new features of both the smartphone and application suggests a sincere interest in the mapping and monitoring tool.

Slight modifications are needed, such as simplifying the menu screen by removing clutter and additional applications, and ensuring every screen in the application is icon-based. As with any form of tool or technology, fishers (as much as researchers) will need to re-familiarize themselves with the system each time it is to be used, particularly if there are long gaps between use. Minor modifications to the user-screens during the pilot mapping did not help women orientate themselves, and using a standardised application will make training and use easier in the future.

This research confirms that it is feasible for women - with limited support from facilitators - to map their intertidal fishing grounds while more detailed mapping of intertidal resources can be more complex, as this depends on the mobility of the species in question. In the case of pen shells and oysters, it was feasible for women to map the areas where there was either an oyster bed, or a high density of pen shells. For octopus however, the mapping was conducted over areas of substrate (rocky

intertidal) where women reported high catches octopus. If this mapping were extended to *Madada*, then it would be predominantly a use zone, where a lot of *Madada* are normally caught. The resulting intertidal resource maps therefore represent core areas where fishers have high catches, rather than all areas where a particular resource occurs. The mapping aims to capture the local resource use areas that are used for harvesting and therefore require sustainable management. The aspiration is not, however, to provide a biological resource assessment, but a participatory assessment collecting information useful for the local resource users.

Despite the apparent ease of mapping, the end-to-end process is time consuming. If PRA techniques are used individually, they are often relatively quick to use, but the design process illustrated in Figure 2 shows that it takes time to introduce the activity, choose participants, conduct the training, and map. Regardless of the existence of this new technology, completing the full mapping of fishing grounds and then intertidal resources remains a relatively labour-intensive exercise. When repeating this process however, preparatory steps such as designing the application are not necessary anymore and the overall timeframe can be shorter.

While the activity can be interesting to local women communities, this does not overcome the short-term time and economic opportunity costs that participants can bear for participating in such exercises. This is particularly true of women who are dependent on intertidal resources and some of the most vulnerable women in coastal communities. This could be overcome by offering a suitable compensation for women for conducting the mapping. When fishing ground mapping is done as a one-off or e.g. annual exercise, and does not involve a high number of women, this would be less of an issue. However, if the technology is used for routine monitoring of intertidal resources, some form of incentive to offset the cost, or adapting the approach to allow monitoring to occur concurrently alongside intertidal harvesting, would be required to make it feasible for women to participate regularly. Ideally, monitoring should be carried out at least annually to see how catch area and weight changes and to keep the women in practice.

In addition to the opportunity cost placed on women, there is also quite a significant time demand on coordinating NGO staff, who introduced the activity to leaders, managed the process to reduce any potential conflicts (for example with fishers' husbands), and to facilitate the process. While this could also be reduced through training women to be able to train other women and men, there will often need to be an additional expert present to download the data and make the maps. Participatory processes can take longer than expert-orientated or top down mapping and monitoring, and can create an additional burden on participants, so the benefits of the process and the outputs discussed below should be considered in relation to these costs.

4.2 Use of the intertidal fishing ground and intertidal resource maps

The resulting maps illustrate the individual intertidal fishing grounds, the size of each fishing ground, and the key intertidal resources harvested within these areas. These maps respond to the original mapping objectives.

When fisherwomen and -men verified the maps, they were able to distinguish key physical features, and the zones themselves. However, as fishers are already aware of these areas, although do not have them in printed or electronic format, there is no obvious added advantage in having these located on a map for discussions between fishers themselves. For fishers own planning, a participatory map (paper or other) would be as useful and quicker to produce. This beggars the question as to the use of the digital maps. In the short-term, these maps will likely be more useful to fisheries managers external to the community, than to fishers themselves. The maps provide information to government and NGOs working with the communities in co-management and are in this respect useful for the communities. The information displayed on the maps, including size and extent of fishing grounds, and where key intertidal resources are located, acts as a tool for conversation between these actors. This allows project staff (government or NGO) to interact with community members based on an understanding of the zones in question, the size and resources in each zone. This is only important in fisheries co-management initiatives that aim to provide technical scientific input into communities' co-management plans, to give appropriate advice on the potential management measures that might be effective in a given zone. In these kinds of initiatives, the maps act as an interface between fishers and external managers.

For example, as CCPs work directly with district governments, the existence of a map to explain areas under different types of management will be an advantage for government to understand, assess, and support communities' plans. While there is no formal requirement to have a map of fishing grounds for CCPs to be legalised or active, as CCPs have the right to manage coastal resources up to three nautical miles offshore (Garnier et al., 2008), CyberTracker could be used to map the exact area of jurisdiction of a CCP and generate a map of this area. Communities seeking formal recognition of a LMMA based on the new conservation legislation in Mozambique (Lei de conservação, 2014), which allows community conservation areas, could use digital maps to demonstrate a zoning plan. Beyond their working relationship with government and NGOs, maps and management plans will be useful for CCPs when discussing with groups external to the community, such as tourism operators who are sometimes also interested in marine conservation. Some fisherwomen are CCP members and thereby directly involved in negotiations and sustainable management.

In addition to being a communication and potential management tool to help communities work with groups external to their community, possibly more importantly, the maps provide information on a

meaningful spatial unit, which are recognised as being essential for fisheries management. A combination of the information on the intertidal resources in the zone, communities' management objectives, and scientific knowledge, will allow management of this area. An obvious case in point is the introduction of temporary reserves for octopus in Madagascar, which include both a temporal and spatial component, are reliant on scientific knowledge of octopus ecology, and based on areas selected by fishers themselves (Oliver et al., 2015).

Catch data is an important parameter for sustainable management and often corresponding location data is lacking (Samoilys et al., 2017). The maps allow for fisheries catch data to be linked to the intertidal fishing ground where the catch was taken, with knowledge of the habitat type in this zone, the size and location (Samoilys et al, in prep). This improves the quality of the analysis of catch data, and allows data to be disaggregated for areas under management and not under management. Therefore, the resulting maps could serve as the basis for monitoring of fisheries catch, meaning that CPUE data is spatially explicit. While this is possible with participatory paper maps, these digital maps have information on the size, exact location and resources from each fishing ground.

In addition to some of the potential uses of the maps for fisheries monitoring and management, the maps have the additional advantage of providing documented evidence of use of fishing grounds by the communities in this coastal region. Taking into account the development context in the region, such as plans to establish a transboundary marine protected area (MPA) between northern Mozambique and southern Tanzania, high-level tourism developments, and hydrocarbon exploration and development activities (Guerreiro et al., 2011; WIOMSA, 2011), the formal recognition of fishing grounds through the generation of maps could serve to support and protect communities' claims and rights in the future. Participatory resource maps sketched on cloth, while a useful item for community management decision-making, are unlikely to have the weight of scientifically-based maps generated using a GPS. In the Congo Basin maps made from GPS data collected by Pygmy hunter-gatherers are used increasingly frequently to demonstrate community claims to sacred trees in forestry concessions, and to protect peoples' forest lands and resources against conservationists (Nelson and Venant, 2008; Lewis, 2012).

4.3 Integrating fisherwomen's knowledge into marine monitoring and management

Lewis (2012) describes the GPS unit as 'ambivalent' in its role to allow Pygmy groups in the Congo Basin to support their claims for recognitions and rights – the technology itself can be used as much to undermine rights or to support them, but how the technology is applied, to what end, and the process and outcomes are of course more important.

In this case, despite the introduction of a new technology for the actual mapping work, the overall process (Figure 2) relied heavily on traditional PRA techniques such as seasonal calendars and participatory mapping. These techniques were designed specifically to understand local people's perception and knowledge of their own environments (Chambers, 1997). The use of a smartphone does not diminish the importance of the participatory approach and use of these techniques, but adds an accessible tool for local generation of a map. Interestingly while traditional participatory resource mapping usually involves 8-10 people, to capture a range of natural resource users, ages and therefore knowledge types, the limits to the number of smartphones available automatically reduced the number of people producing the knowledge. The combination of these techniques is therefore beneficial because the participatory map incorporates a larger group of people and helps to capture values and perceptions (Lynam et al., 2007) associated with resource use while CyberTracker accurately records geographic data.

During the process, while it was clearly laid out at the start that the goal was to design an approach with the potential to integrate fisherwomen's knowledge into marine monitoring and management, there were parts of the approach and process that seemed extractive. There were times when the women were fully engaged resulting in a sense of empowerment, and that their access to new knowledge was potentially transformative. As Lawrence (2006) argues, rather than a simple dichotomy of instrumental or transformative participation, something more dynamic is happening: women might be empowered to learn about a new technology, and ensure that their local reality is represented on a map, while at the same time data is being extracted, analysed remotely, and the map only returns several weeks later in its final form. And when it does arrive, its practical application is not yet clear. But something has happened that recognises women's knowledge, and puts them at the centre of a process to document that knowledge.

There was also an element of pride at being involved in the monitoring activity, as women showed an interest in the technology and their knowledge of how the smartphone application functions. Probably more importantly, the activity appeared to be enjoyable, and women were relaxed and interactive out in the intertidal zone. The use of the phones appeared to increase women's confidence between themselves and in the community. Being able to go out to the intertidal zone, get away from the village and household tasks, and men, is part of intertidal harvesting: being able to go and have fun during the mapping is important. In similar exercises in Congo Basin countries, researchers from Forest Peoples' Program have also found that community-based mapping using smartphones is enjoyable, and can reinforce traditional knowledge, and encourage mutual respect between younger and older people (Nelson and Venant, 2008).

The ease at which the maps were generated illustrates that women's knowledge of the location and abundance of intertidal resources can be documented and included in discussions and decisions on the most appropriate marine management measures, be they octopus temporary reserves or in-situ oyster management. The additional benefit of this approach is that it requires people to go out to the intertidal flats to discuss the resources and change. This is similar in nature to transect walks, where the idea is to engage people in discussion while in the space and observing the subject matter (Pretty et al., 1995). The mapping process is a good entry point for discussions around marine management. It is a practical and interesting activity to engage women.

While the approach focused on women fishers, the involvement of men was required throughout the process from initial permission from local leaders, permission of women's husbands, and the women were accompanied on a daily basis by the vice-leader of the village to supervise activities. The gender and sociocultural norms in Quiwia require that women are accompanied when working with external men, such as the male AMA technicians. Fisheries co-management legislation requires the participation of at least 30% women in Mozambique (Regulamento da Pesca Marítima, 2003), but women are rarely active participants. The OSOL project has supported women to establish an informal group, *Mudanca* (change) to represent intertidal harvesters in CCP meetings. There was some suggestion from women that putting women at the centre of map making, and discussions about intertidal resources has had a noticeable effect on women's participation in fisheries management meetings and CCP meetings in the village. To date the maps have now been used to establish a temporary reserve, with a focus on octopus management. While this has come about with the support of an external project, the support from the broader community for this initiative does suggest that fisherwomen now have more of a role in fisheries-management.

5 Conclusions

In summary, it can be stated that CyberTracker is a simple monitoring tool that stimulates interest in monitoring work and offers possibilities for participation of illiterate people. Due to its icon-based user interface it proved to be suitable for working with the women in Quiwia. Using CyberTracker is a good short-term solution to integrate illiterate fisherwomen into intertidal resource management. While the long-term goal must be to improve literacy of women in Mozambique, the mapping application used here allowed the women to present their knowledge to outside actors. CyberTracker is effective as a GPS data collection method, especially in combination with participatory mapping and therewith, the aim should be a combination of established PRA and recent technological methods to achieve the best possible outcome. We recommend, however, to carry out the digital mapping with more participants and we highlight again that this was a pilot study. The maps can be easily generated from the data and are useful as a communication tool with outside actors from government and NGOs. Additionally, the maps could support claims of resource use areas to authorities as well as help to

establish LMMAs. The applications can easily be adapted, which offers the possibility to include more data, such as catch rates, and to map other resource use sites, such as subtidal areas.

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6 References

ADNAP (2012) *Para um Sistema Descentralizado de Gestão das Pescarias Artesanais de Moçambique.*,

Anderson S. C., Flemming J. M., Watson R. and Lotze H. K. (2011) Rapid Global Expansion of Invertebrate Fisheries : Trends, Drivers, and Ecosystem Effects. **6**, 1–9. Available at: 10.1371/journal.pone.0014735.

Aswani S. and Weiant P. (2004) Scientific Evaluation in Women's Participatory Management: Monitoring Marine Invertebrate Refugia in the Solomon Islands. *Hum. Organ.* **63**, 301–319.

Baralt M. (2011) Coding Qualitative Data. In *Research Methods in Second Language Acquisition: A Practical Guide*. (eds. A. Mackey and S. M. Gass). Wiley-Blackwell. pp. 222–244.

Barnes-Mauthe M., Oleson K. L. L. and Zafindrasilivonona B. (2013) The total economic value of small-scale fisheries with a characterization of post-landing trends : An application in Madagascar with global relevance. *Fish. Res.* **147**, 175–185. Available at: <http://dx.doi.org/10.1016/j.fishres.2013.05.011>.

Basurto X., Gelcich S. and Ostrom E. (2013) The social – ecological system framework as a knowledge classificatory system for benthic small-scale fisheries. *Glob. Environ. Chang.* Available at: <http://dx.doi.org/10.1016/j.gloenvcha.2013.08.001>.

Béné C. and Neiland A. E. (2006) *From Participation to Governance. A critical review of the concepts of governance, co-management and participation, and their implementation in*

- small-scale inland fisheries in developing countries.*, WorldFish Center and CGIAR Program on Water and Food, Perpustakaan Negara Malaysia.
- Blythe J. L., Murray G. and Flaherty M. S. (2013) Historical Perspectives and Recent Trends in the Coastal Mozambican Fishery. *Ecol. Soc.* **18**. Available at: <http://dx.doi.org/10.5751/ES-05759-180465>.
- Carlton J. T. (1993) Neoextinctions of Marine Invertebrates. *Am. Zool.* **33**, 499–509. Available at: <http://www.jstor.org/stable/3883715>.
- Chambers R. (1994a) Participatory Rural Appraisal (PRA): Challenges, Potentials and Paradigm. *World Dev.* **22**, 1437–1454.
- Chambers R. (1994b) The Origins and Practice of Participatory Appraisal. *World Dev.* **22**, 953–969.
- Chambers R. (1997) *Whose Reality Counts? Putting the first last.*, Intermediate Technology Publications, London, UK.
- Conrad C. C. and Hilchey K. G. (2011) A review of citizen science and community-based environmental monitoring : issues and opportunities. *Env. Monit Assess* **176**, 273–291. Available at: <http://dx.doi.org/10.1007/s10661-010-1582-5>.
- CyberTracker Conservation (2013a) CyberTracker. Available at: <http://www.cybertracker.org/software/step-by-step-tutorial>.
- CyberTracker Conservation (2013b) CyberTracker - Our Story. Available at: <http://www.cybertracker.org/background/our-story>.
- Danielsen F., Jensen A. E., Alviola P. A., Balete D. S., Mendoza M., Tagtag A., Custodio C. and Enghoff M. (2005) Does monitoring matter ? A quantitative assessment of management decisions from locally-based monitoring of protected areas. *Biodivers. Conserv.*, 2633–2652. Available at: <http://dx.doi.org/10.1007/s10531-005-8392-z>.
- Daw T., Maina J., Cinner J., Robinson J., Wamukota A., Gerry C., Abunge C., Thoya P., Abernethy K., Cedras M., Mwaura J. and Ndegwa S. (2011) *The spatial behaviour of artisanal fishers : Implications for fisheries management and development (Fishers in Space)*.,
- Eades G. L. (2015) *Maps and Memes: Redrawing Culture, Place, and Identity in Indigenous Communities.*, McGill-Queen's University Press.
- Fröcklin S., de la Torre-Castro M., Håkansson E., Carlsson A., Magnusson M. and Jiddawi N. S. (2014) Towards Improved Management of Tropical Invertebrate Fisheries : Including Time Series and Gender. *PLoS One* **9**. Available at: <http://dx.doi.org/10.1371/journal.pone.0091161>.

730 Garnier J., Silva I., Davidson J., Hill N., Muaves L., Mucaves S., Guissamulo A. and Shaw A.
 731 (2008) *Co-Management of the Reef at Vamizi Island, Northern Mozambique.*,
 732 Guerreiro J., Chircop A., Dzidzornu D., Grilo C., Ribeiro R., van der Elst R. and Viras A.
 733 (2011) The role of international environmental instruments in enhancing transboundary
 734 marine protected areas : An approach in East Africa. *Mar. Policy* **35**, 95–104. Available
 735 at: <http://dx.doi.org/10.1016/j.marpol.2010.06.013>.
 736 Harley C. D. G., Hughes A. R., Hultgren K. M., Miner B. G., Sorte C. J. B., Thornber C. S.,
 737 Rodriguez L. F., Tomanek L. and Williams S. L. (2006) The impacts of climate change
 738 in coastal marine systems. *Ecol. Lett.* **9**, 228–241. Available at:
 739 <http://dx.doi.org/10.1111/j.1461-0248.2005.00871.x>.
 740 INE (2013) Estatísticas do Distrito Palma. , 32.
 741 Jackson J. B. C., Kirby M. X., Berger W. H., Bjorndal K. A., Botsford L. W., Bourque B. J.,
 742 Bradbury R. H., Cooke R., Erlandson J., Estes J. A., Hughes T. P., Kidwell S., Lange C.
 743 B., Lenihan H. S., Pandolfi J. M., Peterson C. H., Steneck R. S., Tegner M. J. and
 744 Warner R. R. (2001) Historical Overfishing and the Recent Collapse of Coastal
 745 Ecosystems. *Science* (80-.). **293**, 629–637. Available at:
 746 <http://dx.doi.org/10.1126/science.1059199>.
 747 Jamieson G. S. (1993) Marine Invertebrate Conservation : Evaluation of Fisheries Over-
 748 Exploitation Concerns. *Am. Zool.* **33**, 551–567. Available at:
 749 <http://www.jstor.org/stable/3883719> .
 750 Jiddawi N. S. and Öhman M. C. (2002) Marine Fisheries in Tanzania. *Ambio* **31**, 518–527.
 751 Available at: <http://www.jstor.org/stable/4315303>.
 752 Kaplan W. A. (2006) Globalization and Health Can the ubiquitous power of mobile phones be
 753 used to improve health outcomes in developing countries ? *Global. Health* **14**, 1–14.
 754 Lawrence A. (2006) “No Personal Motive?” Volunteers, Biodiversity, and the False
 755 Dichotomies of Participation. *Ethics, Place Environ.* **9**, 279–298. Available at:
 756 <http://dx.doi.org/10.1080/13668790600893319>.
 757 Lei de conservação (2014) *Lei n. º 16/2014.*,
 758 Lewis J. (2012) Technological Leap-frogging in the Congo Basin, Pygmies and Global
 759 Positioning Systems in Central Africa: What has happened and where is it going? *Afr.*
 760 *Study Monogr.*, 15–44.
 761 Ling S. and Milner-Gulland E. J. (2006) Assessment of the Sustainability of Bushmeat
 762 Hunting Based on Dynamic Bioeconomic Models. *Conserv. Biol.* **20**, 1294–1299.
 763 Available at: <http://dx.doi.org/10.1111/j.1523-1739.2006.00414.x>.

764 Lynam T., Jong W. De, Sheil D., Kusumanto T. and Evans K. (2007) A Review of Tools for
 765 Incorporating Community Knowledge, Preferences, and Values into Decision Making in
 766 Natural Resources Management. *Ecol. Soc.* **12**. Available at:
 767 <http://www.ecologyandsociety.org/vol12/iss1/art5/>.
 768 Mackinson S. and Nøttestad L. (1998) Combining local and scienti ® c knowledge. *Rev. Fish*
 769 *Biol. Fish.* **8**, 481–490.
 770 Nelson J. and Venant M. (2008) *Indigenous peoples’ participation in mapping of traditional*
 771 *forest resources for sustainable livelihoods and great ape conservation.*,
 772 Oliver T. A., Oleson K. L. L., Ratsimbazafy H., Raberinary D., Benbow S. and Harris A.
 773 (2015) Positive Catch & Economic Benefits of Periodic Octopus Fishery Closures : Do
 774 Effective , Narrowly Targeted Actions “ Catalyze ” Broader Management ? *PLoS One*,
 775 1–24. Available at: <http://dx.doi.org/10.1371/journal.pone.0129075>.
 776 Pretty J. N., Guijt I., Thompson J. and Scoones I. (1995) *A Trainers Guide for Participatory*
 777 *Learning and Action.*, IIED Participatory Methodology Series, London.
 778 Regulamento da Pesca Maritima (2003) *Regulamento da Pesca Maritima.*,
 779 Republic of Mozambique (2008) *Report on the Millennium Development Goals Mozambique*
 780 *2008.*,
 781 Richmond M. D. (2011) *A Field Guide to the Seashores of Eastern Africa and the Western*
 782 *Indian Ocean Islands.*, SIDA/WIOMSA.
 783 Roccliffe S., Peabody S., Samoilys M. and Hawkins J. P. (2014) Towards A Network of
 784 Locally Managed Marine Areas (LMMAs) in the Western Indian Ocean. **9**. Available
 785 at: <http://dx.doi.org/10.1371/journal.pone.0103000>.
 786 Rogers D., McCann T. and Cooper A. (2010) Integrating paper-based habitat mapping with
 787 mobile electronic field recording procedures. *Ecol. Inform.* **5**, 479–483. Available at:
 788 <http://dx.doi.org/10.1016/j.ecoinf.2010.06.004>.
 789 Rosendo S., Brown K., Joubert A., Jiddawi N. and Mechisso M. (2011) A clash of values and
 790 approaches : A case study of marine protected area planning in Mozambique. *Ocean*
 791 *Coast. Manag.* **54**, 55–65. Available at:
 792 <http://dx.doi.org/10.1016/j.ocecoaman.2010.10.009>.
 793 Samoilys M. A., Osuka K., Maina G. W. and Obura D. O. (2017) Artisanal fisheries on
 794 Kenya’s coral reefs : Decadal trends reveal management needs. *Fish. Res.* **186**, 177–191.
 795 Available at: <http://dx.doi.org/10.1016/j.fishres.2016.07.025>.
 796 Spellerberg I. F. (2005) *Monitoring Ecological Change.*, Cambridge University Press.
 797 Tucker B., Tombo J., Hajaso P., Nagnisaha C., Lahitoka V. R. and Zahatsy C. (2013)

Beyond Mean and Variance: Economic Risk Versus Perceived Risk of Farming,
Foraging, and Fishing Activities in Southwestern Madagascar. *Hum. Ecol.*, 393–407.
Available at: <http://dx.doi.org/10.1007/s10745-013-9563-2>.

WIOMSA (2011) *Migrant fishers and fishing in the Western Indian Ocean: Socio-economic
dynamics and implications for management.*,

Wong P. P., Losada I. J., Gattuso J.-P., Hinkel J., Khattabi A., McInnes K. L., Saito Y. and
Sallenger A. (2014) Coastal systems and low-lying areas. In *Climate Change 2014:
Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects.
Contribution of Working Group II to the Fifth Assessment Report of the
Intergovernmental Panel on Climate Change* (eds. C. B. [Field, V. R. Barros, D. J.
Dokken, K. J. Mach, M. D. Mastrandrea, T. E. Bilir, M. Chatterjee, K. L. Ebi, Y. O.
Estrada, R. C. Genova, B. Girma, E. S. Kissel, A. N. Levy, S. MacCracken, P. R.
Mastrandrea, and L. L. White). Cambridge University Press, Cambridge, UK and New
York, USA. pp. 361–409.

Figure 1

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Figure 2

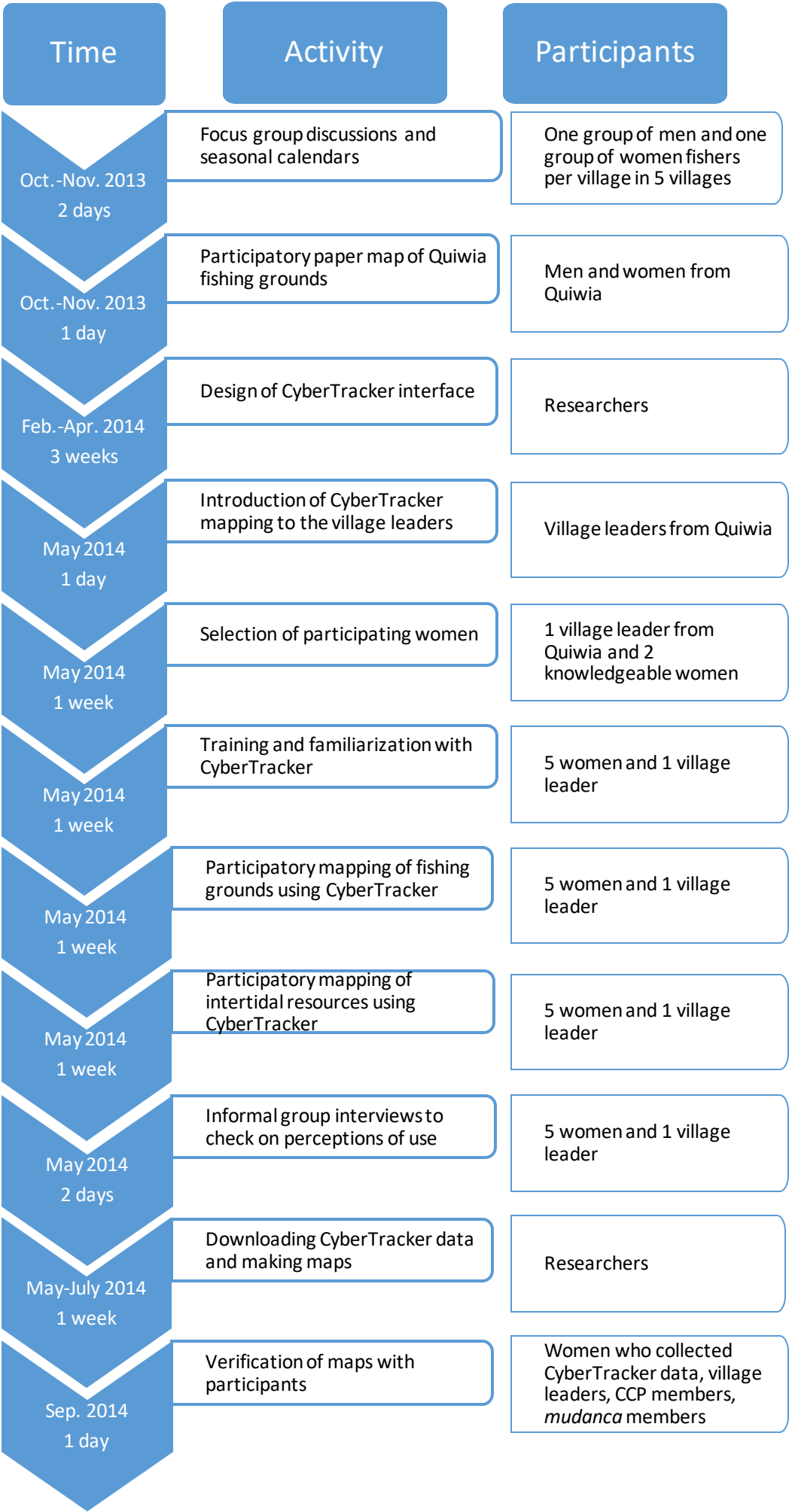


Figure 3
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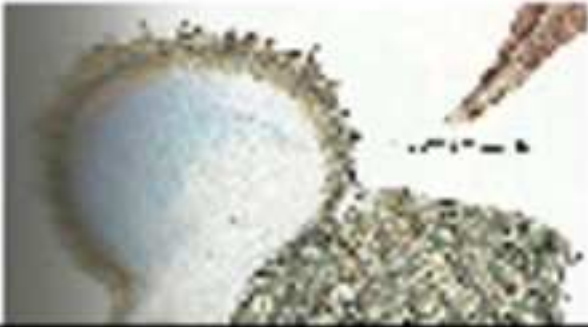
Type of Animal		
Mweja		▲ ≡
Makaza		
Imbare		▼
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Figure 4
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Figure 5
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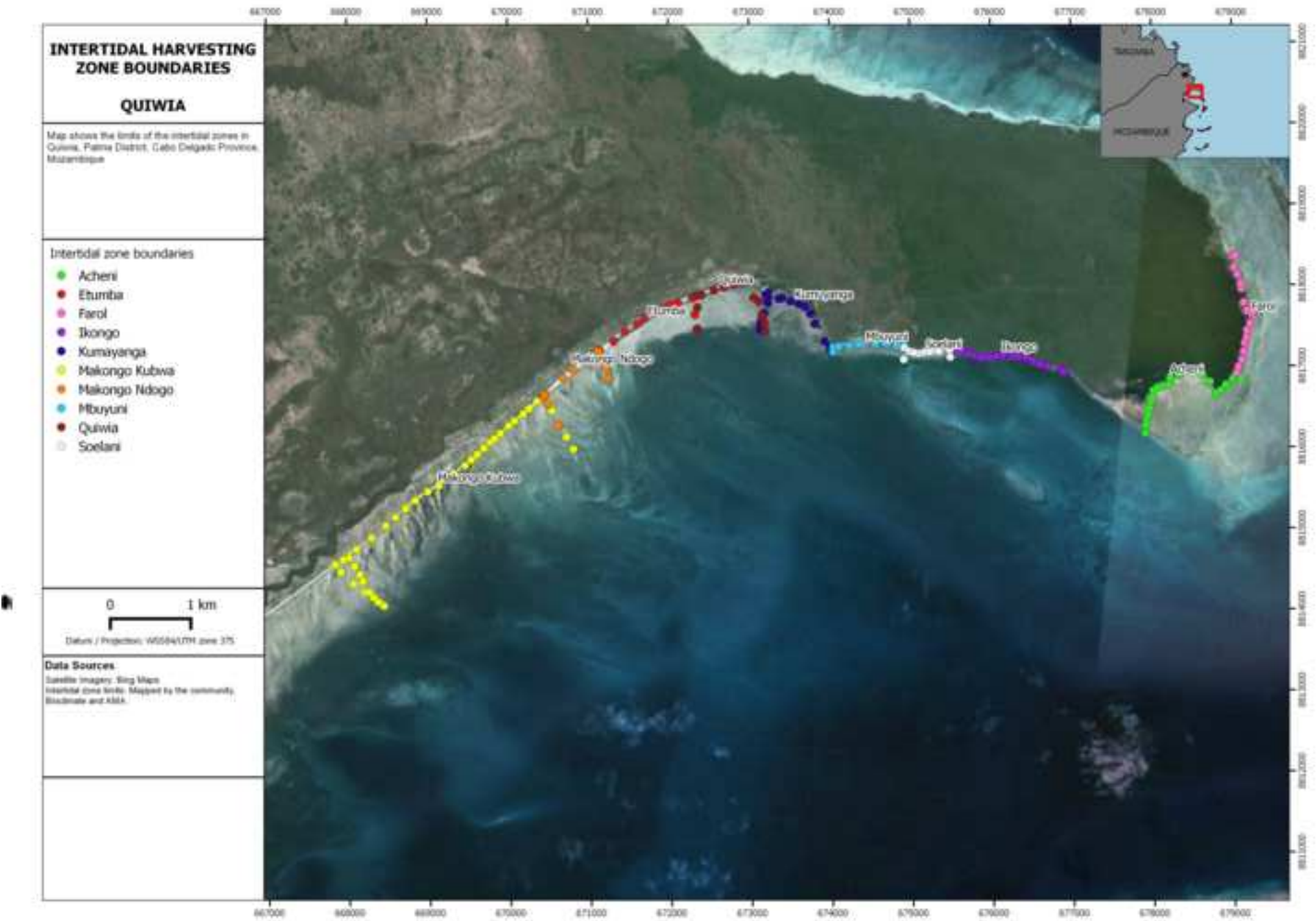


Figure 6
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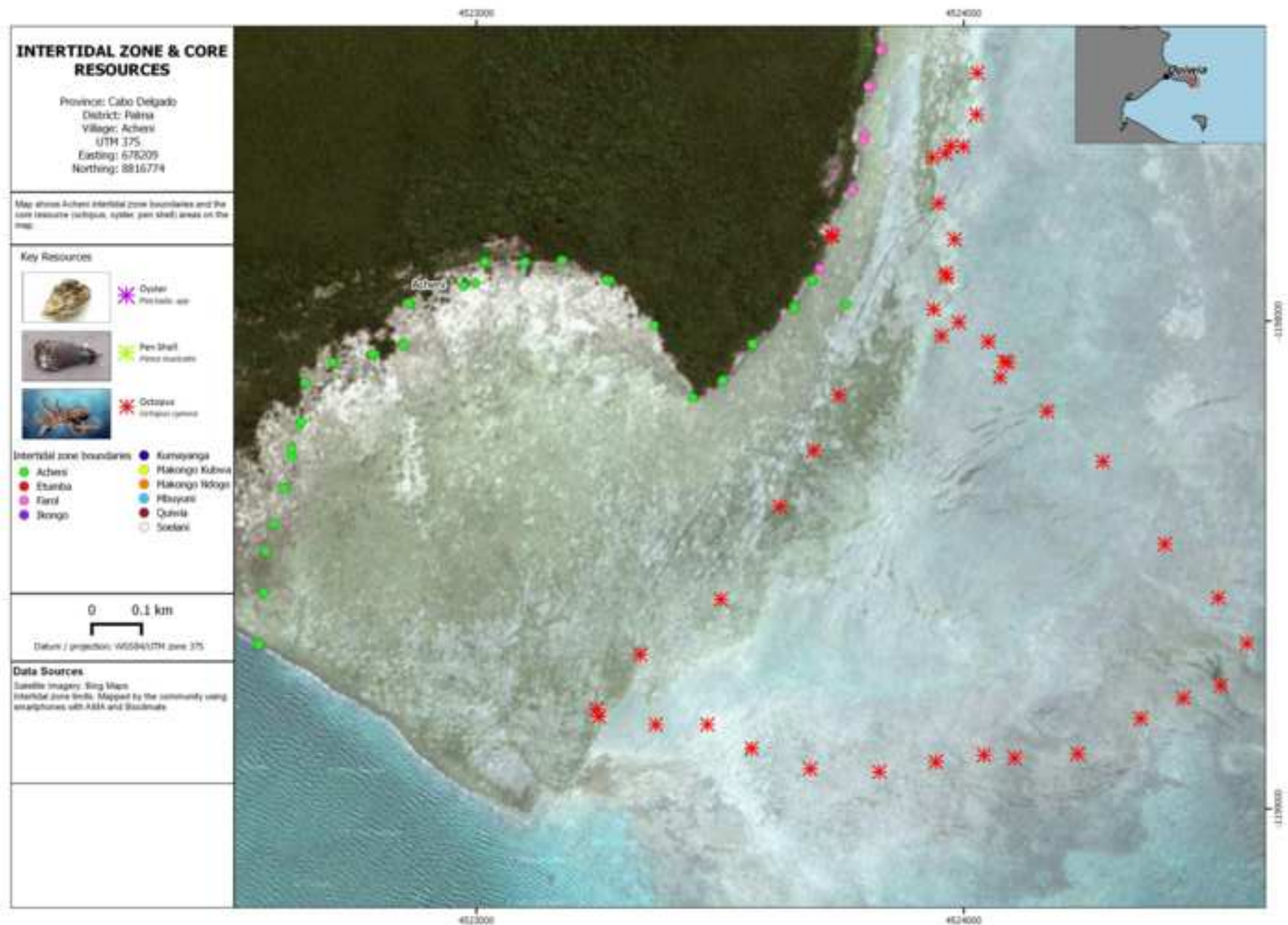
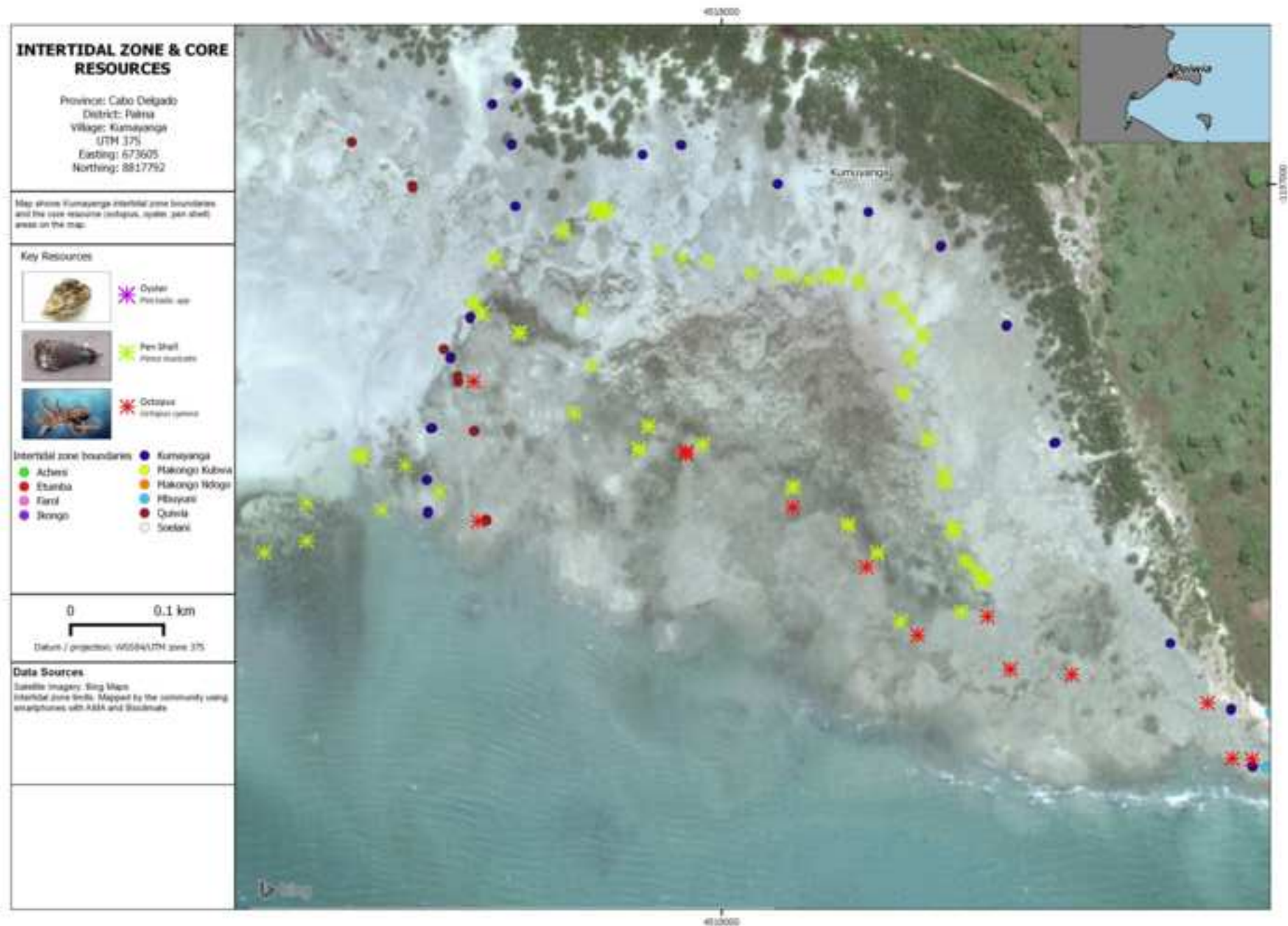


Figure 7
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The authors' responses are all in italics and bold.

Reviewer #1: Summary:

This article outlines a pilot project regarding the use of smartphone technology (CyberTracker software) as a tool for mapping of fisheries resources and the value of such an approach for facilitating increased community involvement in local resource management. A participatory approach (including interviews, focus groups and training sessions) was promoted to a previously under-accessed knowledge base (local fisherwomen), so as to access their considerable local knowledge of the area and provide them opportunity for involvement in fisheries management decisions. Local women reef gleaners of Cabo Delgado (Mozambique) were the target group in the study, and results indicate that community-based mapping is an effective tool for management of a local resource.

Introduction:

-Overall, introduction is clear and well-written with good coverage of previous work; some minor re-wording of sentences needed for improved grammar/readability

-lines 57-61 - sounds clunky and repetitive; consider re-wording

We condensed and reworded this section accordingly. (Now lines 51-55)

-lines 79-80 - reword sentence (sounds as if elderly are in the intertidal zone)

We restructured the sentence to make clear that the elderly are not in the intertidal zone. (Now lines 71-73)

-lines 91-96 - reword sentence

We split the sentence to make this section more understandable. (Now lines 84-89)

-lines 119-121- reword sentence

We reworded this sentence. (Now 112-114)

-Perhaps authors could mention other threats to invertebrates aside from overfishing? E.g. effects of climate change to invertebrate populations? Threat of increased population growth?
We added in the first paragraph of the introduction, that invertebrates are also threatened by climate change and pollution (lines 54-55). The authors feel that increased population growth is one of the issues leading to overharvesting, so we did not address this explicitly in the paper again to avoid repetition.

-lines 147-151 - can authors please expand on this? Would be interesting to hear more about the potential problems associated with CyberTracker technology

We thank the reviewer for this comment. This section was slightly reworded and we tried to make clearer that CyberTracker is just a tool and not a solution, which shows that technology use in the third world is not one of our main themes but just a side topic. Our focus lies on the participatory strategy. Information on technical problems associated with CyberTracker are

presented in our results (lines 338-396) and we do not want to preempt too much of our results in the introduction.

Methodology:

-Overall, clear methodology but writing need to be improved throughout. There are a number of poorly worded sentences and very short sentences that could be combined with other statements. Likewise, figures and tables need improvement to be suitable for publication.

Edits to the writing were done throughout as suggested by the reviewer.

-what software company is behind CyberTracker? Would like more information. Are there other benefits/disadvantages to using CyberTracker besides those listed? Information is lacking.

CyberTracker is a non-profit organization and to our knowledge no software company is behind it. We clarified that again in section 2.3, lines 202-206 and added another source from the website for this information.

There are no other benefits or disadvantages to CyberTracker that we came across during our research except those already mentioned.

-Figure 1 caption could be improved (explanation of red/yellow dots, study area, map source)
The caption was improved.

-Figure 2 figure and caption could be improved. Caption is rather vague.

Additional information was added to the caption and text boxes were improved. More information linked to the table was also added in lines 485-487.

-Tables 1 and 2 needs improving, caption should be above table.

Captions were moved above the tables. Table 1 caption was improved. The layout of Table 2 was improved and changes to the content made to make it easier to understand.

-I am wary of the fact that only three smart phones were used between six women - is this sufficient for providing an accurate map of resources/fishing areas?

We thank the reviewer for this comment. We added additional information about accuracy throughout the methods part. Lines 258-260: the location of the intertidal fishing grounds is common knowledge and therefore a few participants are enough to represent this knowledge. We also stressed again, that a larger group of fisherwomen and -men were included in the participatory mapping and therewith provided input as well (lines 295-300). Nevertheless, we also agree that it would be beneficial to incorporate more people in the mapping in the future and we made this clear again (lines 295-300).

Results:

-Results are clear but lacking as seem to overwhelmingly focus on the act of mapping itself with little attention given to the actual resulting maps - are they accurate? are they helpful? are

they a useful tool to marine managers? is there some way authors could have measured/analysed this?

We already addressed the points regarding accuracy in the previous responses. The usefulness of the maps was discussed in more detail throughout the discussion.

-how did the researchers determine if the mapping was accurate? It would be helpful to have been provided with quantitative data to gauge how accurate the final results were. Could the researchers not have completed the exercise as well and compared their own results to those of the women? Or provided a comparison of results from each pair of women or other fishermen/women?

Lines 291-292: all women mapped the same areas, so a comparison between the women is possible. Additionally, we reworded this part to highlight that the researcher collected data as well and could therefore validate the data collected by fisherwomen (lines 292-294).

-a map can only be useful if it is accurate - there is no test of this.

We addressed the accuracy in various comments above and think that within the scope and purpose of our research accuracy was sufficiently verified. We elaborated the purpose of our mapping again in lines 476-479.

Discussion:

-authors discuss integration of maps into management and monitoring but it seems a fairly large leap from the simple maps provided in the maps to effective management - please say more about this.

We agree that it is a large step from mapping to management. The short-term use of the maps is more in form of a communication tool than a management tool between communities and government or NGO staff working together in co-management. We elaborated this point in more detail in lines 514-528.

We expanded lines 552-559 to explain benefits of linking digital maps and CPUE data and added two new references that support the importance of digital location data.

Women's engagement ensures that resources important to their livelihoods make it into the management discussion and management plans.

Overall:

The paper is clearly written but rather simplistic and the results are unsurprising. Figures and Tables (including captions) needs improvement to be suitable for publication. Likewise, some sections need re-writing. I would like to have seen more rigorous testing of the tool (e.g. more participants) and ground-truthing conducted by other groups/survey data. As it stands now, one is unsure how successful the mapping actually was as there is no benchmark against which to test it. A fairly large leap is made by the authors from the use of the technology for mapping areas to actual effective marine management of intertidal species. Greater discussion is needed to provide indication of how the mapping tool would accurately inform management.

Despite my above misgivings, I do think the work stands as an important contribution to community-based participatory mapping. The application of an accessible technological tool to marine management in developing regions is clearly of great value. Results may effectively inform community-based mapping, and therefore are valuable to community-based management initiatives. Further, the empowerment of certain social groups (in this case, fisherwomen) to be involved in local management is of high of value and should be promoted to other marine managers/management schemes.

I recommend that this article be published after some considerable revision to address issues with the writing. I also encourage the authors to emphasize the pilot nature of this study and clearly recommend that future use of the tool should include greater numbers of participants and repeat measures of study areas to ensure reliability of results.

We added in the conclusion that more participants could be beneficial and that our project was a pilot study.

Reviewer #3: The paper proposes participatory mapping as a valuable instrument for involving women for co-managing coastal fisheries. The status of less educated women in LDC are given primacy in the paper making the paper so important for less studied aspects in threatened coastal resources. The highlights of the study put premium on the use of simple tools like the software mentioned in the study and scaffolds the notion that IT/ICT integration in fisheries management provide great promise. As in other countries to map the different intertidal fishing grounds, will be important in planning and implementation of fisheries management programs.

I have very few comments:

1. Are these fisherwomen the wives of the fishermen? If so, the need to highlight said status can be added in the paper.

We thank the reviewer for this comment but we do not see the relevance of including the livelihood activities of these women's husbands as part of this paper. It is very rare to see a paper about fishermen which has to qualify their wives' livelihood activities.

2. In line 120...Despite the prevalence of these techniques, maps are still more available and common in government, NGO and private sector offices in urban areas than in the rural coastal communities that they pertain to..." This is the condition in Mozambique? What's the source of this?

Yes, this is the case in Mozambique. We added this information.

This situation was observed by the authors. Maps are rarely available in fishing communities but often available to the other actors.

3. In line 526 to 527 "... CCPs should seek support from other groups external to the community, such as the increasing number of tourism lodges in the region, when being able to present and discuss maps and management..." What then will be the role of "illiterate fisherwomen" in this context? They will just simply be used by researchers prove the efficacy of the smartphone but not to provide sustainable solutions?

We rephrased this paragraph and added the information requested by the reviewer. Some fisherwomen are members of the CCP and thereby directly involved in the local management and in providing sustainable solutions (lines 540-541).

4. The use of simple tool, can be considered here however the cost of the gadget must also be noted also?

We added in the methods section (lines 235-236) that the NGO project Our Sea Our Life financed the smartphones.

5. Lines 566 to 567 ..." use of a smartphone does not diminish the importance of the participatory approach and use of these techniques, but adds an accessible tool for local generation of a map" This assertion needs further elucidation and also show the facts.

We thank the reviewer for this comment but think that we address this point already in the introduction in more detail (lines 140-146) and show in Figure 2 the overall participatory approach. We therefore did not want to be too repetitive and did not elaborate the same point again here.

The title "Piloting participatory smartphone mapping of intertidal fishing grounds and resources in northern Mozambique: opportunities and future directions" appears to lack coherence with the conclusion written which puts much premium on the efficacy of using CyberTrack. The purpose of highlighting illiterate fisherwomen, the participatory mode, the generation of maps will not erase the doubt that the ultimate aim is to introduce or to determine the efficacy or effectiveness of the gadget which may not be within the reach of the local community as to the cost?. The author(s) may have tried to hide the real intent of "testing the gadget" instead of really addressing Mozambique's issue on the illiteracy of women as understudied sector and also capitalize on the "participatory" in order to realize the hidden intent of the maker of the CyberTracker. Why capitalize on these issues on illiterate fisherwomen or participatory approach in co-management when the real intent is to test the usability or workability of the gadget?

We thank the reviewer for the great suggestions in this comment. We changed the conclusion to bring across our point better, that not testing CyberTracker is our main goal here but that incorporating women into fisheries management is the goal and can be achieved by using CyberTracker. The fisherwomen are our main focus and we needed to find a technology that suits them and hence chose CyberTracker, not the other way around. Our method of using CyberTracker does not try to mask the underlying development issues such as illiteracy. This application is a tool that is helpful in the current situation, where women – who are often

illiterate, especially in coastal rural communities, can only be incorporated through this approach. Without the possibilities that CyberTracker offers, the women could not be included into the management. Using CyberTracker is also only a short-term solution, since the long-term goal must be to improve literacy of women in Mozambique. A detailed discussion of this subject is however beyond the scope of this paper but we clearly summarized this point again in the conclusion.

We also tried to change the impression of focusing on CyberTracker too much by changing the language and removed the word CyberTracker a few times throughout the manuscript.

If we try to revisit the technological innovation and the long wave theory (Linstone & Devezas 2012)*. That is, "...In an attempt to distinguish basic innovations from improvement innovations, Devezas has pointed out that basic innovations (like this paper the CyberTracker) ... generate a broad range of human activities... and introduce new, radically different habits and customs in society..." In other words, can the innovation on CyberTracker will have extraordinary socio-economic and cultural impact on the illiterate fisherwomen? Is Devezas' approach in conceptualizing a basic innovation (which is the CyberTracker) has something that profoundly modifies the human activities, customs and habits... of illiterate fisherwomen? Finally, the author(s) must be cautious enough in involving in their research about "innovations" capitalizing on the these underserved and understudied sectors of poverty-stricken fishing villages not

only in Africa but more so in the South or East Asian countries...? *[Technological Forecasting & Social Change 79 (2012) 414-416].

We thank the reviewer for this suggestion but feel that starting a discussion about long-wave theory might be behind the scope of our paper. Since we use the smartphone only for project purposes (the mapping which is likely to only take place once a year) and not for daily use, the impact of this technology should not lead to a profound change in customs and habits in the fisherwomen's lives. The impacts of smartphone use might be different and more influential when utilizing mobile phones to improve communication services, making banking or markets more accessible to people in rural areas, but this is not the case in our project.

Congratulations to the author(s) and thank you for this opportunity to review the paper. I have no reservations in recommending to ACCEPT the paper with none or very little revision.